The SDSS-II Supernova Survey

Masao Sako (KIPAC /Stanford)

Fermilab: J. Frieman (U Chicago), F. DeJongh, H. Lampeitl, J. Marriner, G. Miknaitis

University of Chicago: B. Dilday, R. Kessler, M. Subbarao (Adler Planetarium)

University of Washington: A. Becker

Ohio State University: D. Depoy, J. Marshall, J. Prieto

University of Tokyo: M. Doi, K. Konishi, T. Morokuma, N. Takanashi, K. Tokita, N. Yasuda

University of Portsmouth: B. Bassett, R. Nichol, M. Smith

South African Astronomical Observatory: E. Elson, K. van der Heyden

Rochester Institute of Technology: M. Richmond

Apache Point Observatory: J. Barentine, H. Brewington, J. Dembicky, M. Harvanek, J. Krzesinski, B. Ketzeback, D. Long, O. Malanushenko, V. Malanushenko, R. McMillan, K. Pan, S. Snedden

KIPAC/Stanford University: R. Blandford, S. Kahn, R. Romani, C. Zheng

New Mexico State University: T. Gueth, J. Holtzman

Penn State University: D. Schneider

University of Notre Dame: P. Garnavich

Space Telescope Science Institute: A. Riess

Sloan Digital Sky Survey II Collaboration

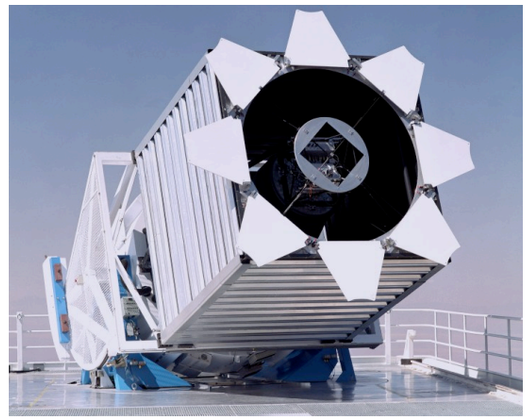
Sloan Digital Sky Survey II

- 3-year extension to the SDSS, which ended on July 2005
- 3 primary scientific components
  - Legacy Survey - complete SDSS
  - SEGUE - Galactic Survey
  - Supernova Survey

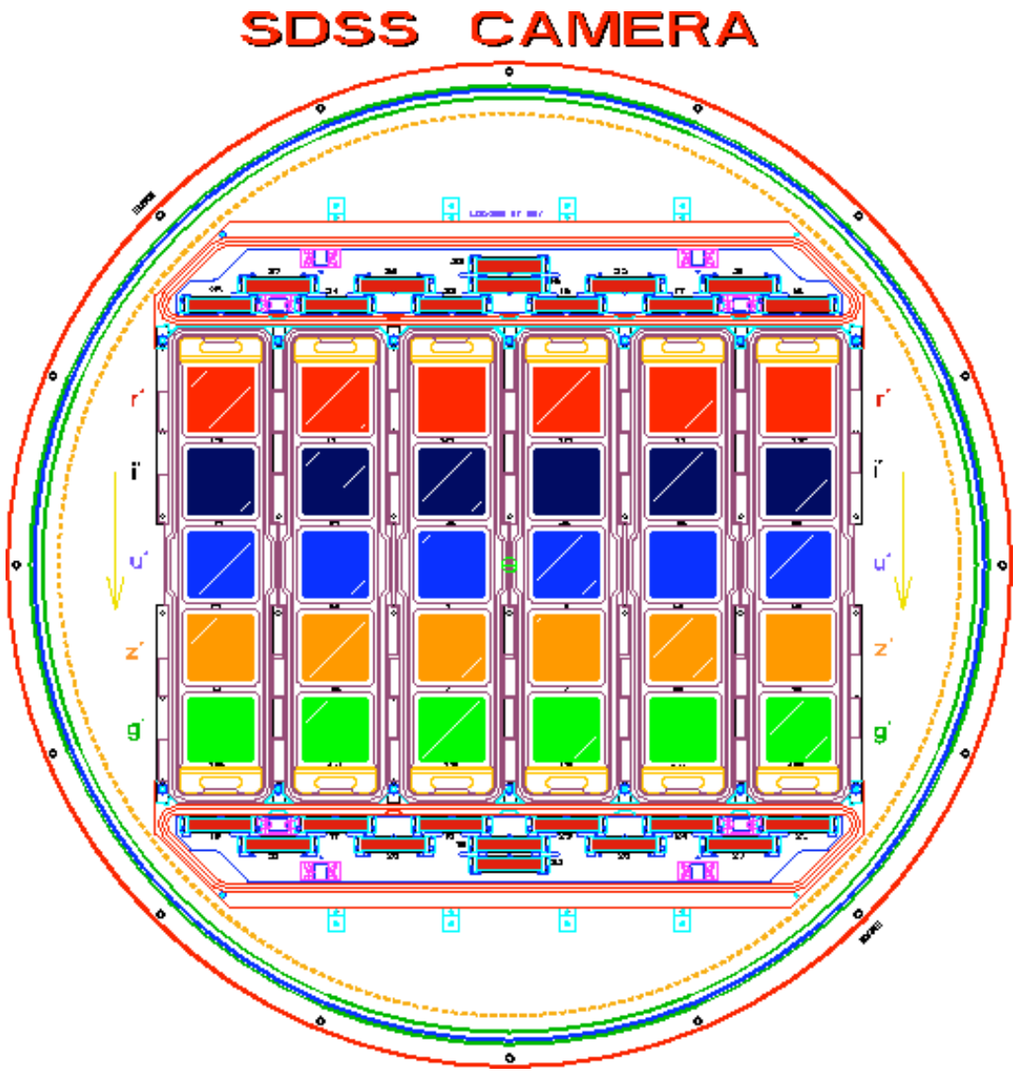
Outline

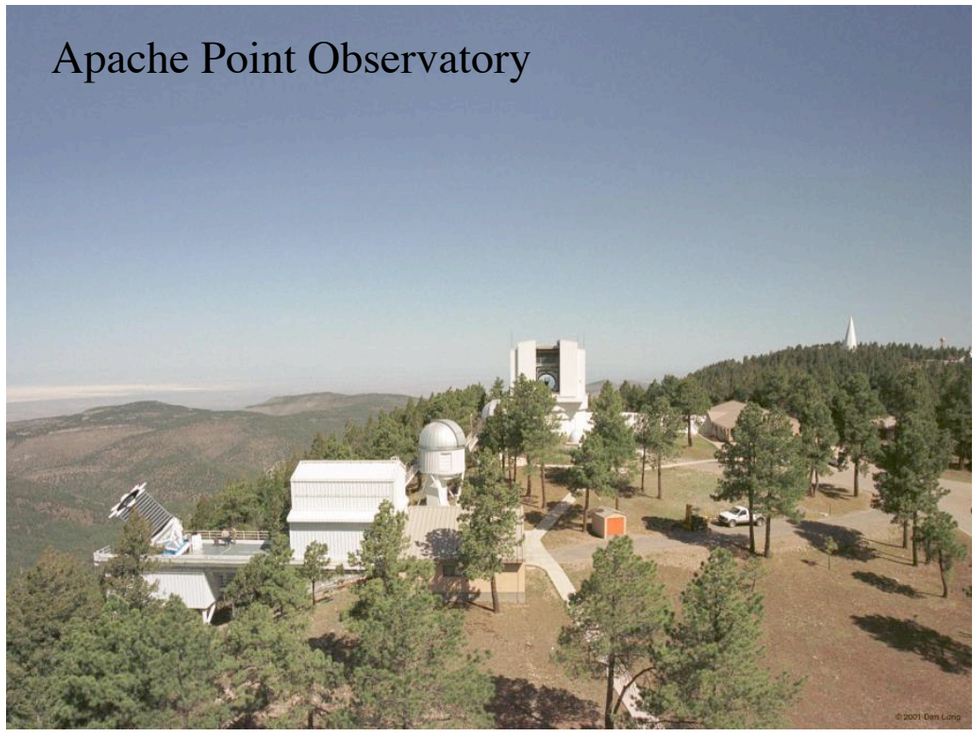
- Brief description of the Supernova Survey.
- Science goals.
- How we find supernovae and plan follow-up.
- Preliminary results from the 2005 run.
- Plans for 2006 (and 2007).

Supernova Survey



- Use the SDSS 2.5m telescope
  - during September 1 - November 30 of 2005-2007
  - to scan 300 square degrees of the sky on a cadence of 2 days
  - discover supernovae and obtain multi-color light curves



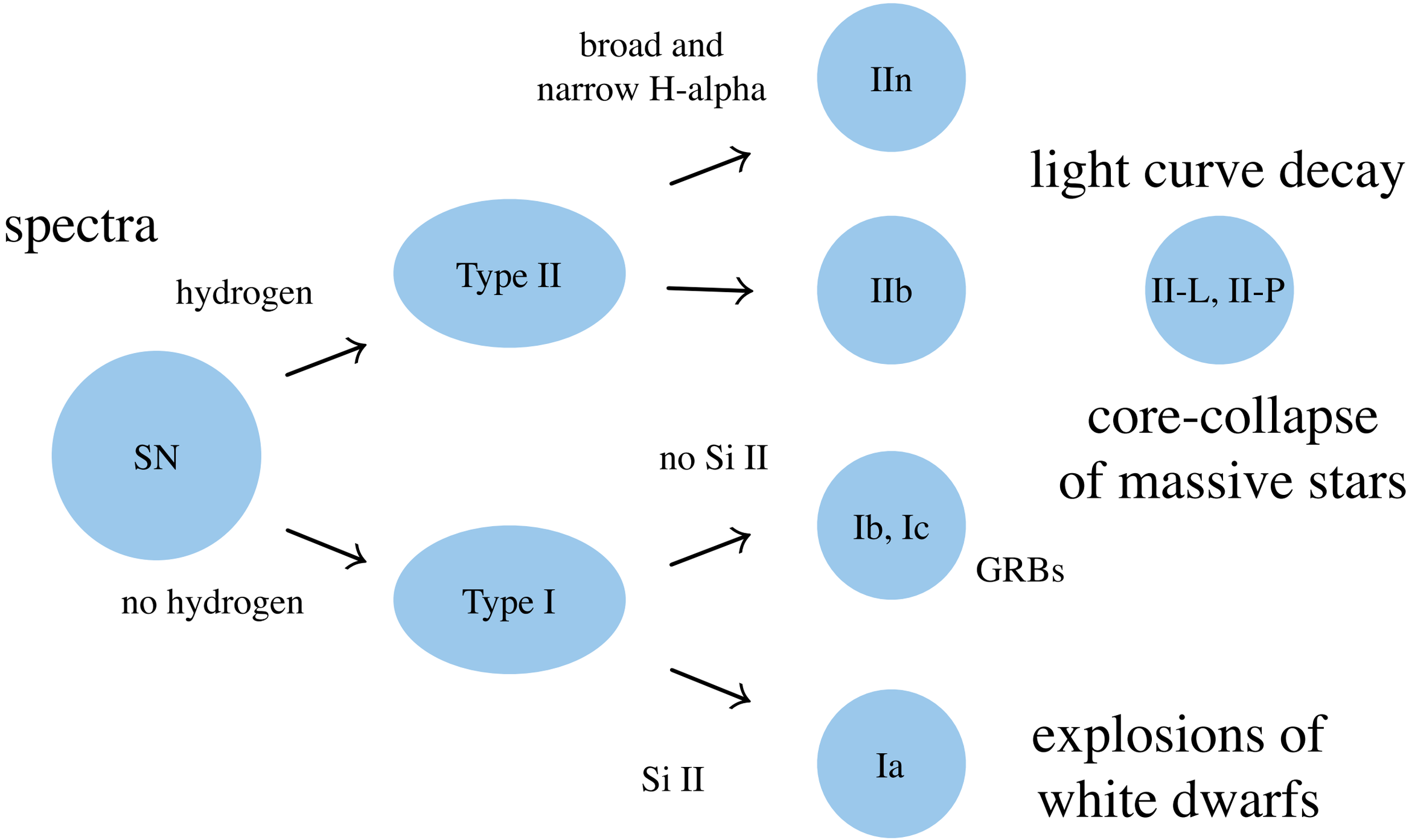


Follow-up program

- Spectroscopic
  - confirm type and measure redshift
  - ARC (3.5m) - 33 half nights; HET (9.2m) - 65 hours of queue time; MDM (2.4m) - 40 nights; WHT (4.2m) - 6 nights; Subaru (8.2m) - 6 half nights

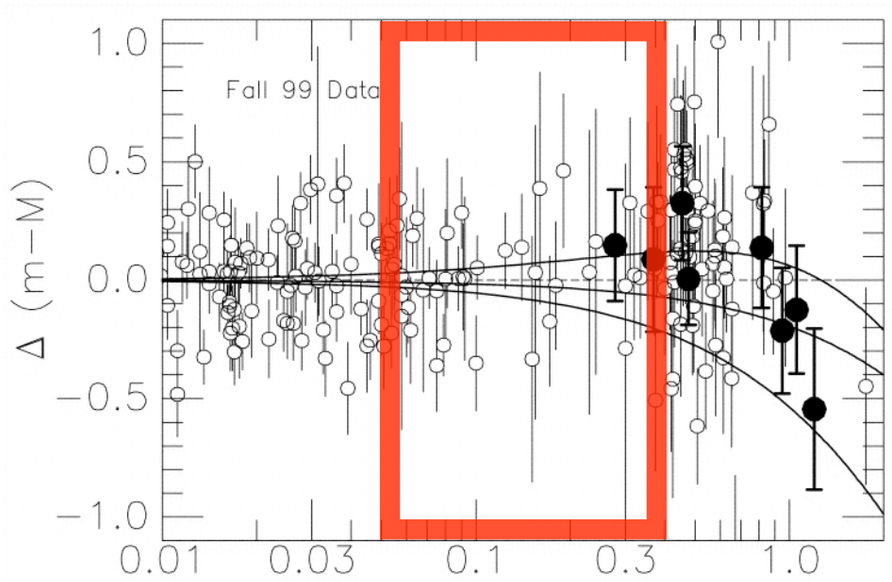
- Imaging
  - fill in/out light curves (poor weather, faint sources)
  - MDM (2.4m) - 40 nights; NMSU (1m) - many nights; UH88 - 5 nights; VATT (1.8m) - 7 nights; WIYN (3.5m) - 2 half nights

SNe are typically classified
according to their optical spectra

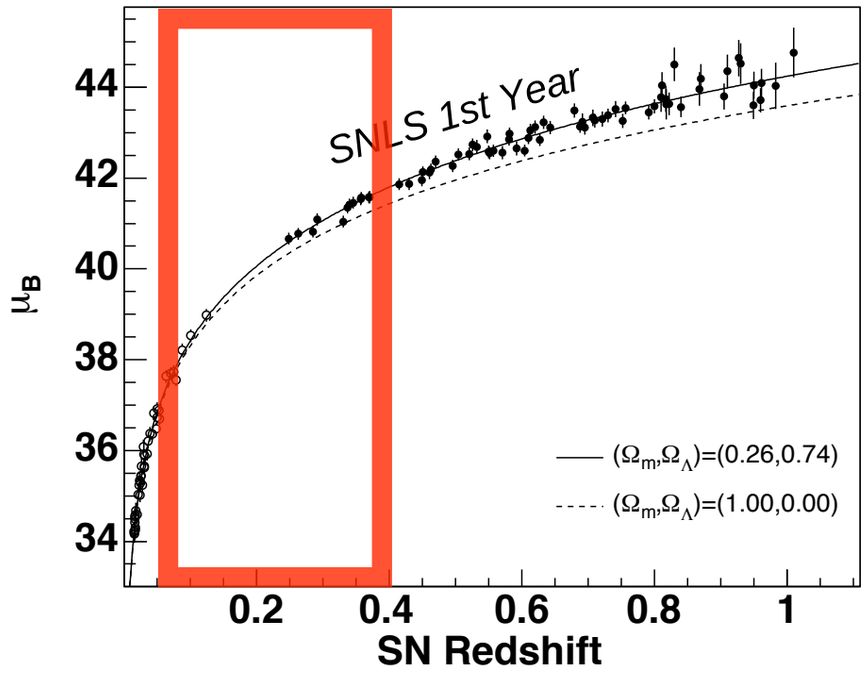


Science goals

- Type Ia supernovae (SNe)
  - spectroscopically confirm and obtain “well-measured” light curves of ~200 SN Ia from z = 0.05 ~ 0.4 (”redshift desert”)
  - bridge low-z (z<0.05; LOSS, SNF) and high-z (0.3<z<1.0; ESSENCE, SNLS) sources
- understand and minimize systematics associated with use of SN Ia as distance indicators
  - SDSS well-understood wavelength response



Tonry et al. (2003)

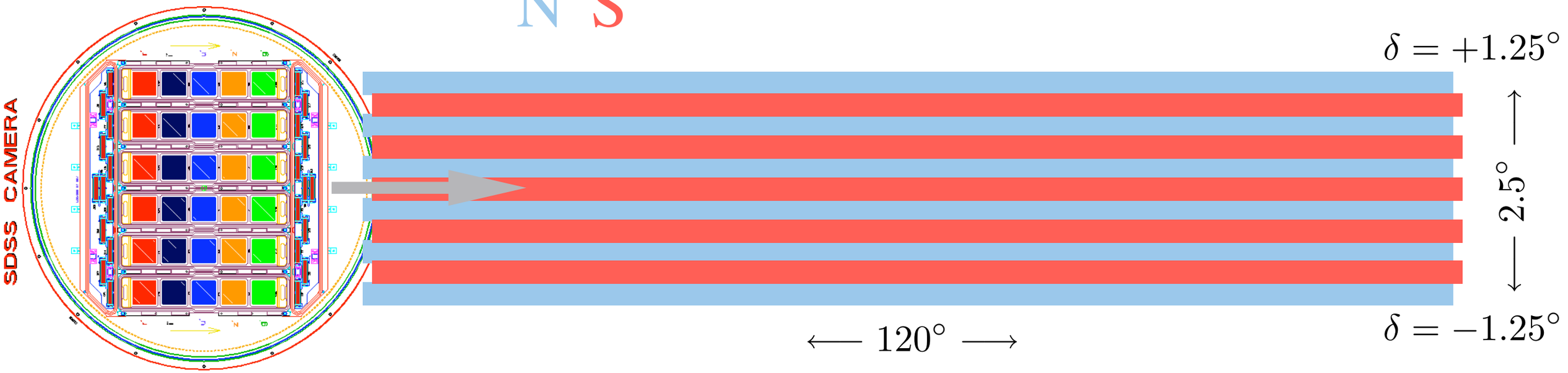


Astier et al. (2005)

- Type II
  - find type II out to z~0.2
  - can we use them as standardized candles (Hamuy & Pinto 2002)?
- Type Ibc
  - only a handful of well-studied objects
  - gamma-ray burst (GRB) association
- Other transients
  - rare types of SNe (peculiar Ia, Ibc hypernova, etc.)
  - asteroids, KBOs, AGNs, variable stars
  - strange transients

Survey area = “stripe 82”

(southern equatorial stripe)



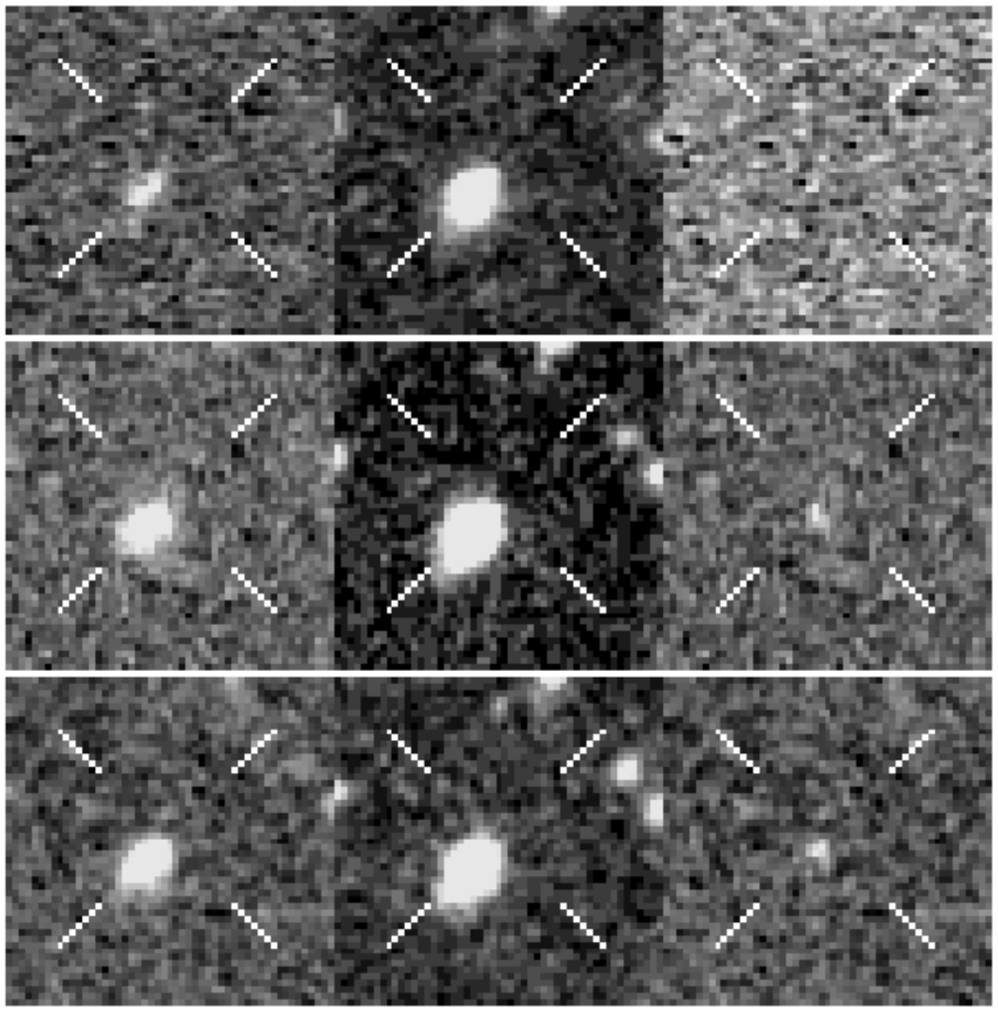
- A “good” full night of imaging results in:
  - 200 GB of reduced images
    - *gri* frames run through a frame subtraction program on dedicated cluster at APO
      - register images, match PSF, zeropoint scaling, etc.
    - search for statistically significant deviations
    - dump known variables, moving objects

add fake SNe

veto catalog

- ~4000 objects transfered to Fermilab for human to scan
- ~600 of them tagged as SNe
- ~300 new “SNe” per night → SN candidates

search template differenced



g (srch, tmplt, subtr)

r (srch, tmplt, subtr)

i (srch, tmplt, subtr)

Scanner	Sako	No updates	All
Obj Id	851749		
srun	5889	sfield	68
trun	826003	tfield	639
rr	10	cc	3
ra	44.933941	decl	-0.343870
gmag		g_delta	
rmag	21.672	r_delta	0.20
imag	21.433	i_delta	0.20
Flags			
Ttl Objects	54		
# Scanned	0		

Back to initializing page.

Manual Scan Guide

- [0] None
- [1] Artefact
- [2] Moving
- [3] Sat. Star
- [4] Dipole
- [5] Variable
- [6] Transient
- [9] Cosmic Ray
- [103] SN GOLD
- [102] SN SILVER
- [101] SN BRONZE
- [100] SN OTHER

Hand Veto

UPDATE

NEXT CAND/SKIP

History for Object Id 851749 By Position

Found 12 previous objects.

Obj Id	srun	trun	rr	cc	ra	decl	MJD	gmag	rmag	imag	Days Before
648741	5760	826003	10	3	44.93394	-0.3439	53665.5	21.94	21.78	21.95	30.9
668948	5771	826003	10	3	44.93397	-0.34385	53668.4	21.61	21.83	21.98	27.9
681316	5776	826003	10	3	44.93397	-0.34388	53669.4	21.6	21.65	21.56	27
682246	5782	826003	10	3	44.93395	-0.34388	53670.5	21.7	22.03	0	25.9

Photometric Typing

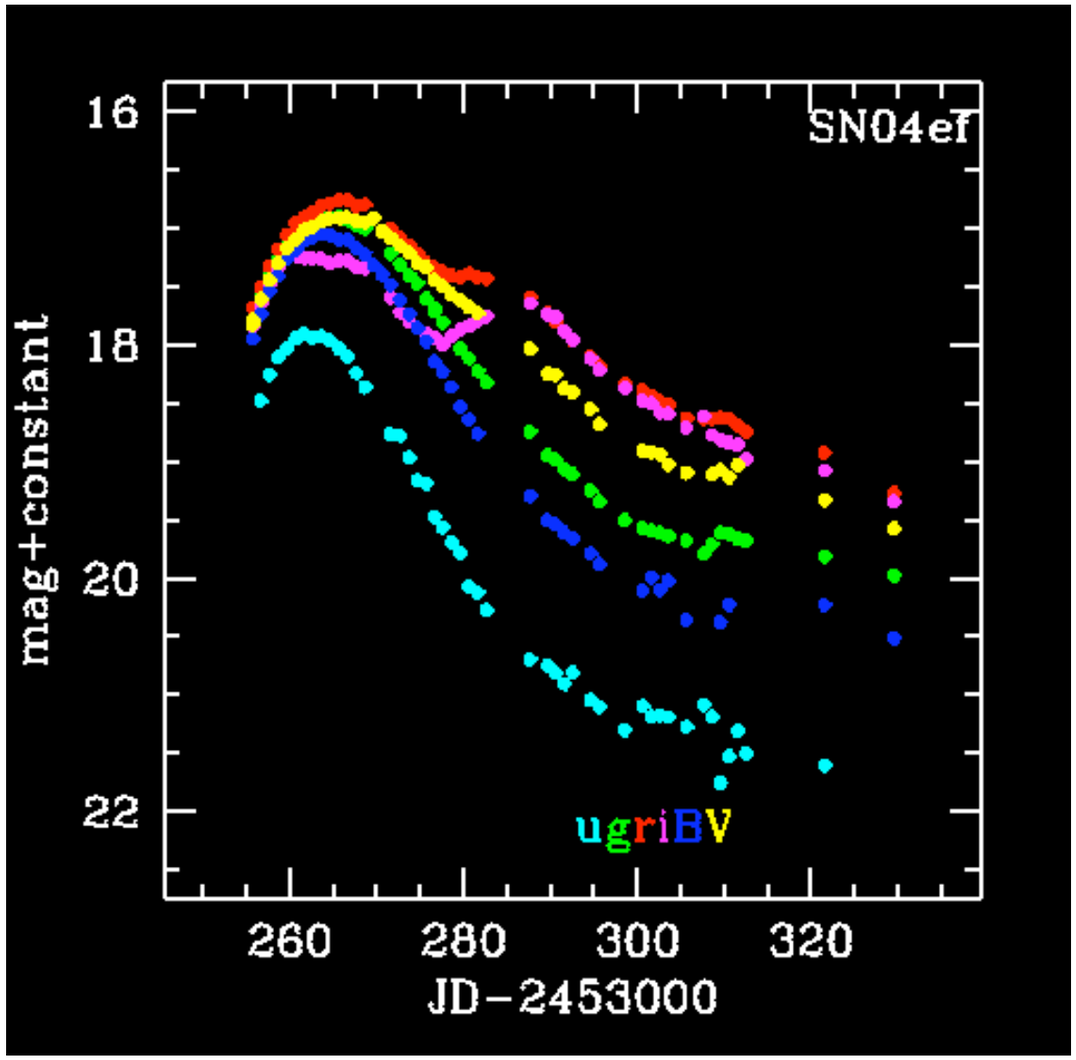
- All of the SN candidates are run through a multi-band light curve fitting code
  - template light curves generated from multi-epoch model spectra (Peter Nugent) and real spectra of other well-observed historical SNe (SUSPECT database)
  - Ia, Ia-pec, II-P, II-L, IIb, Ibc, Ibc-hyp
  - fit parameters = redshift, extinction, stretch for Ia
  - fit observed light curves and find best-matching ones for each SN type
  - repeat nightly

http://supernova.lbl.gov/~nugent/nugent_templates.html
http://bruford.nhn.ou.edu/~suspect/index1.html

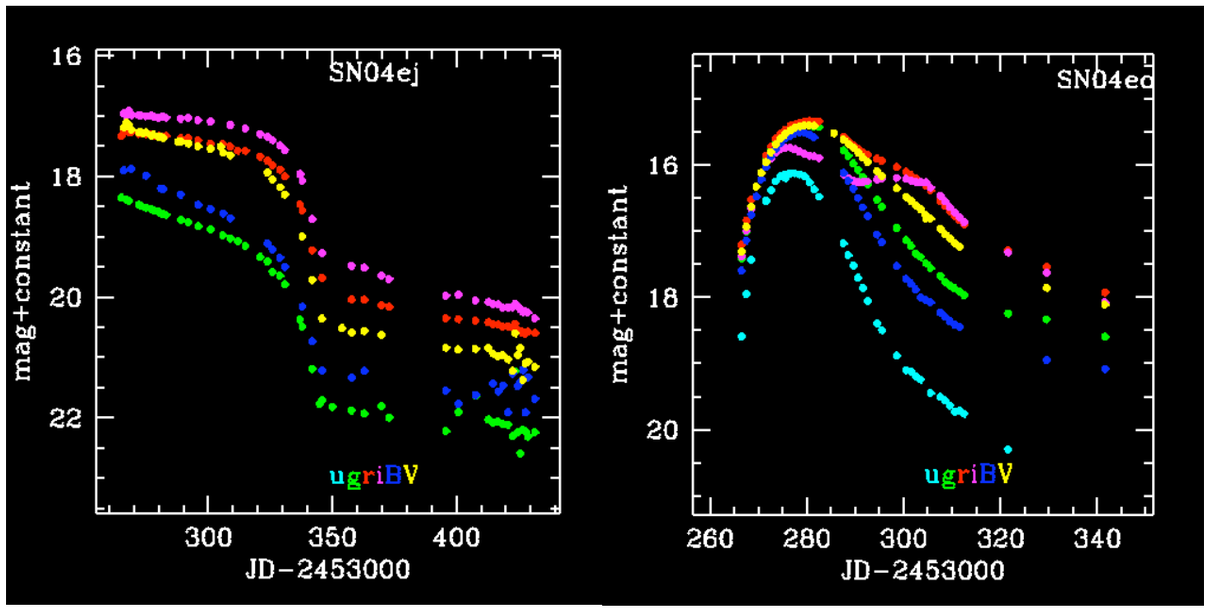
SN Ia light curves

- Peak ~ 20 days after the explosion.
- Decay on a similar timescale.
- Plateau at late time.
- Secondary peak in the red.

Carnegie Supernova Project (CSP)

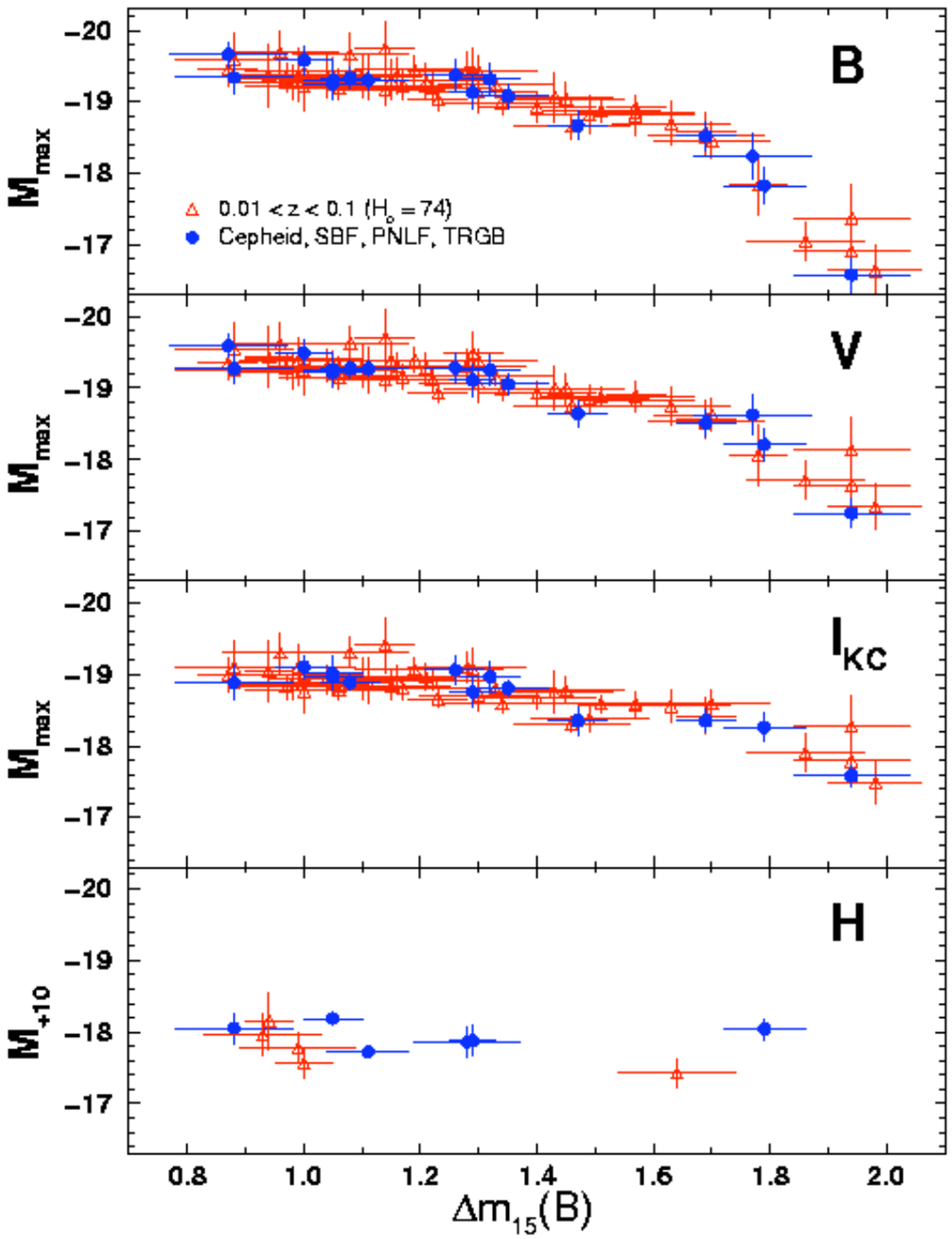


http://csp1.lco.cl/~cspuser1/CSP.html

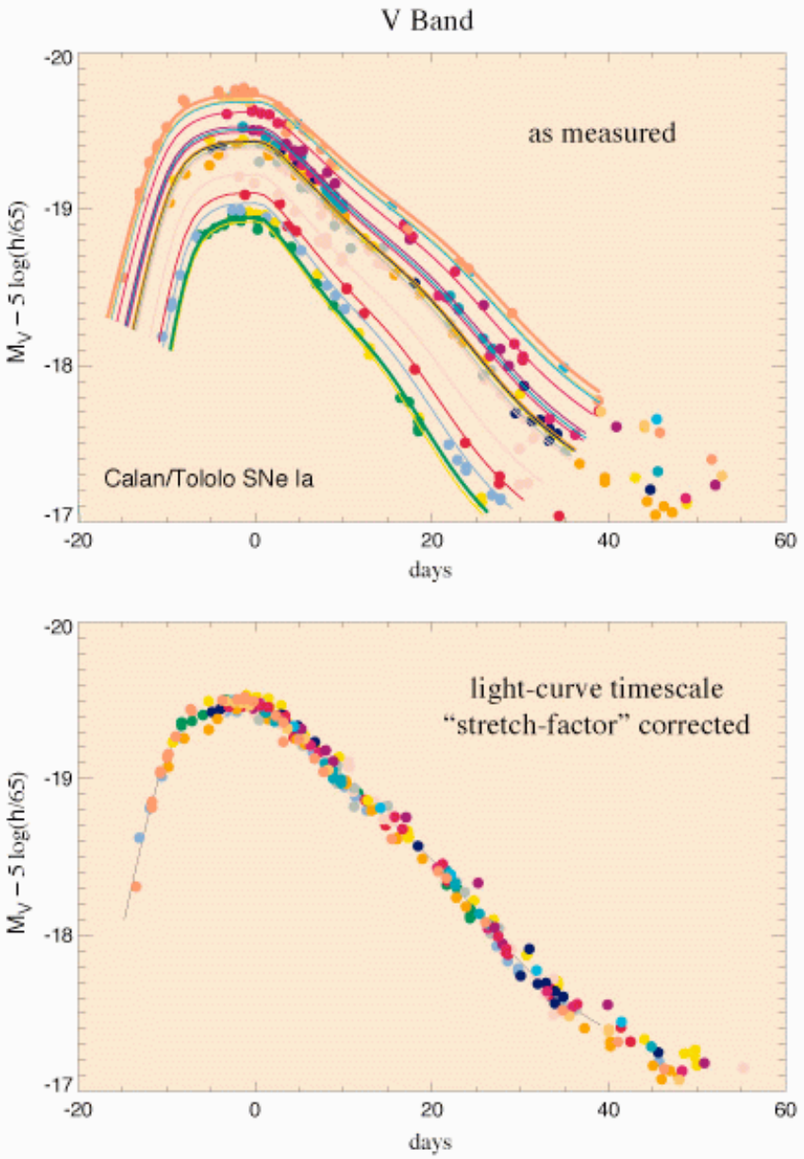


II-P Ia

Type Ia SNe are not standard candles;
they are standardizable

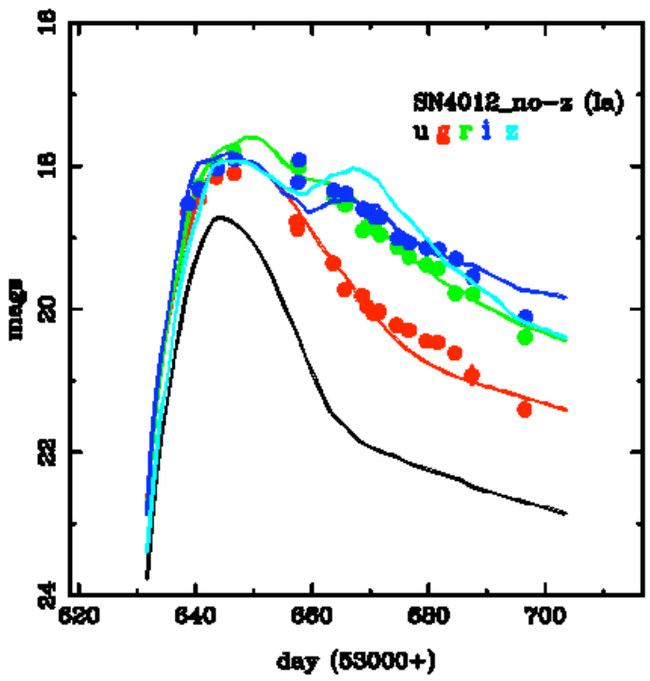


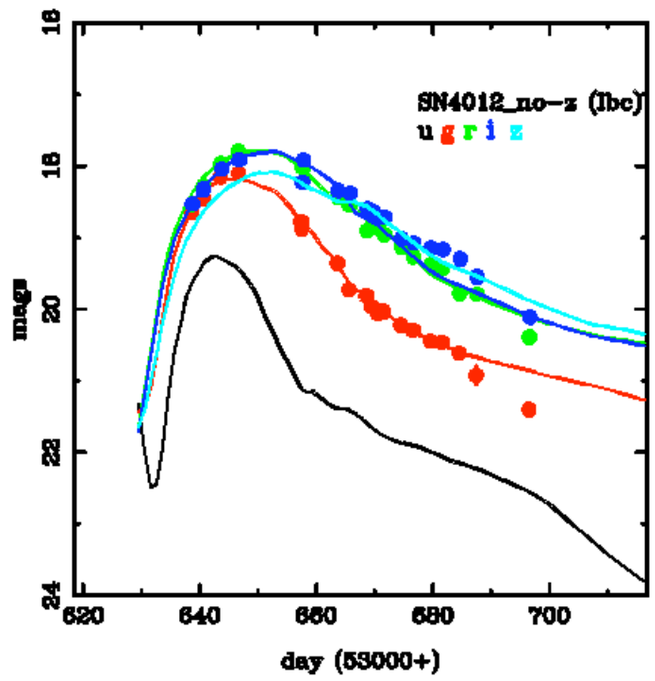
Low Redshift Type Ia Template Lightcurves

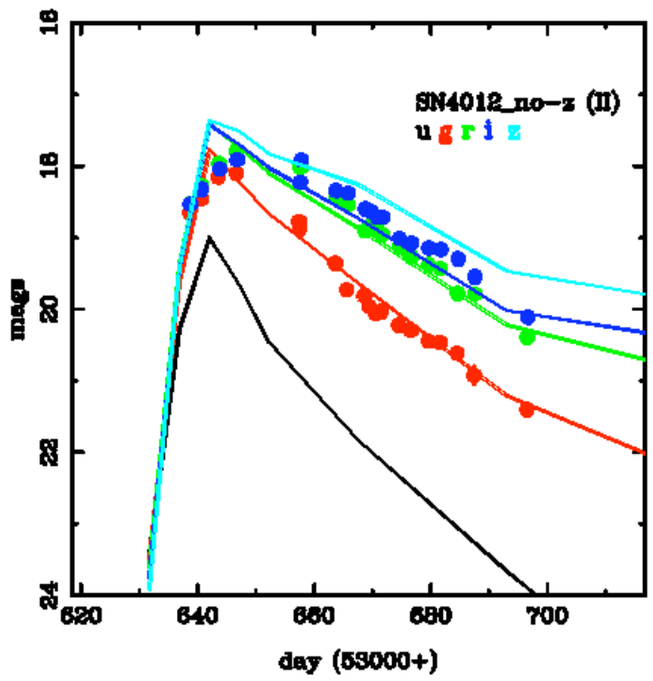


http://www.nd.edu/~kkrisciu/supernovae.html

- Also use SDSS galaxy catalog and search for the nearest host galaxy candidate
  - photo-z as prior
  - estimate contamination by galaxy light
  - estimate dust extinction (morphology, colors, etc.)
- This narrows down the ~300 new SN candidates to ~10 “good” targets for spectroscopic follow up.

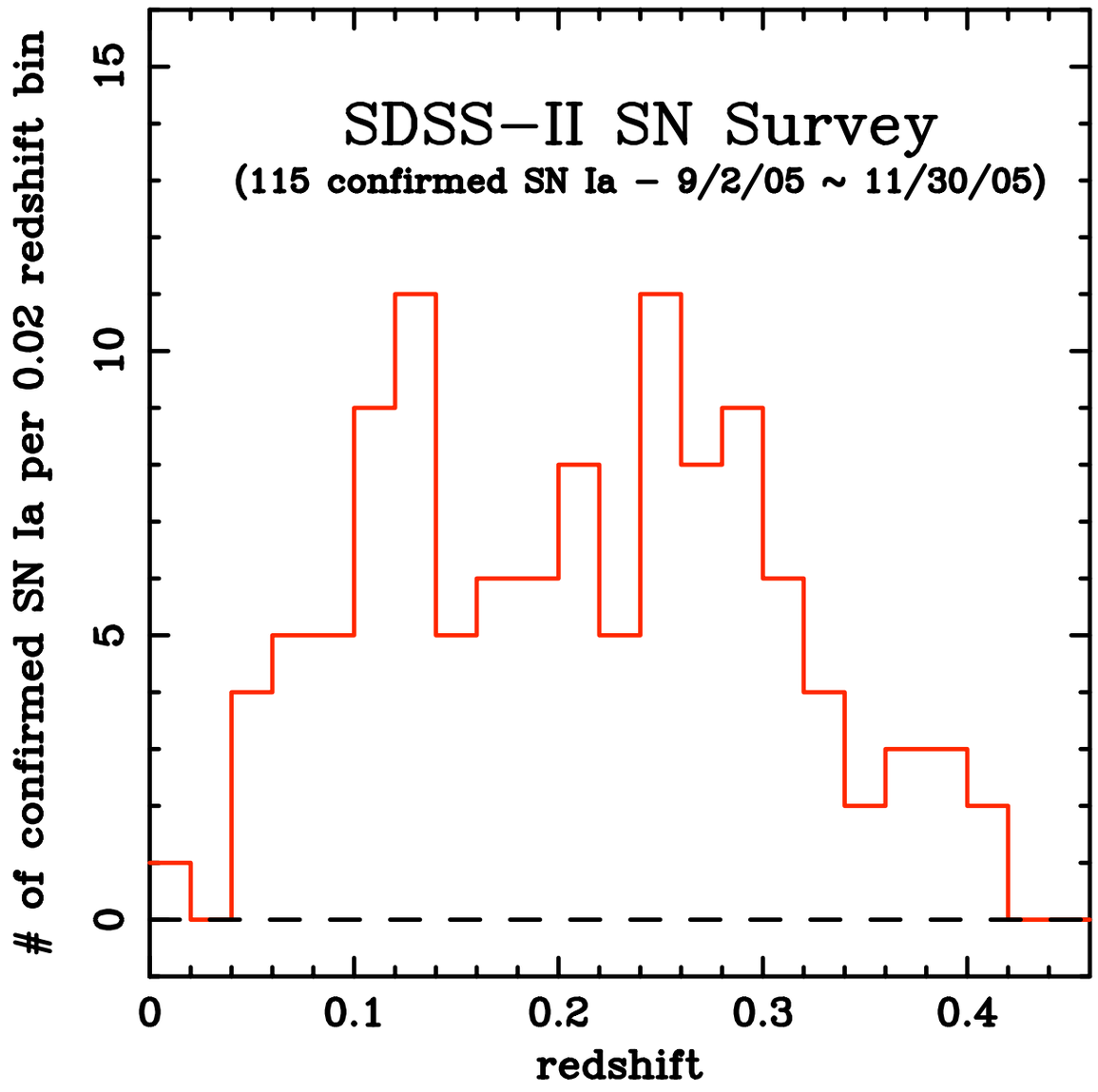


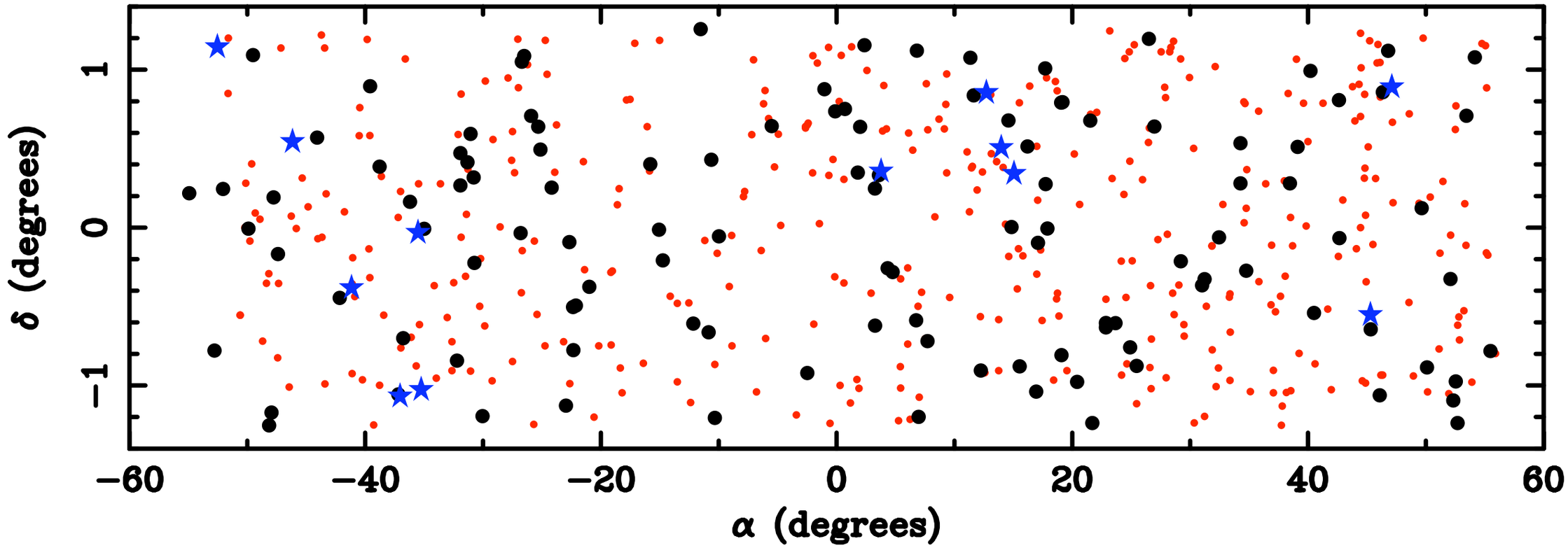




Results from Fall 2005

- Our run ended last night!
  - 115 spectroscopically confirmed SN Ia
  - 12 probable SN Ia
  - 7 SN II (4 type IIn)
  - 5 SN Ib/c (3 hypernovae)
  - 5 AGN
  - ~hundreds of other unconfirmed SNe with good light curves
- Focused on Ia



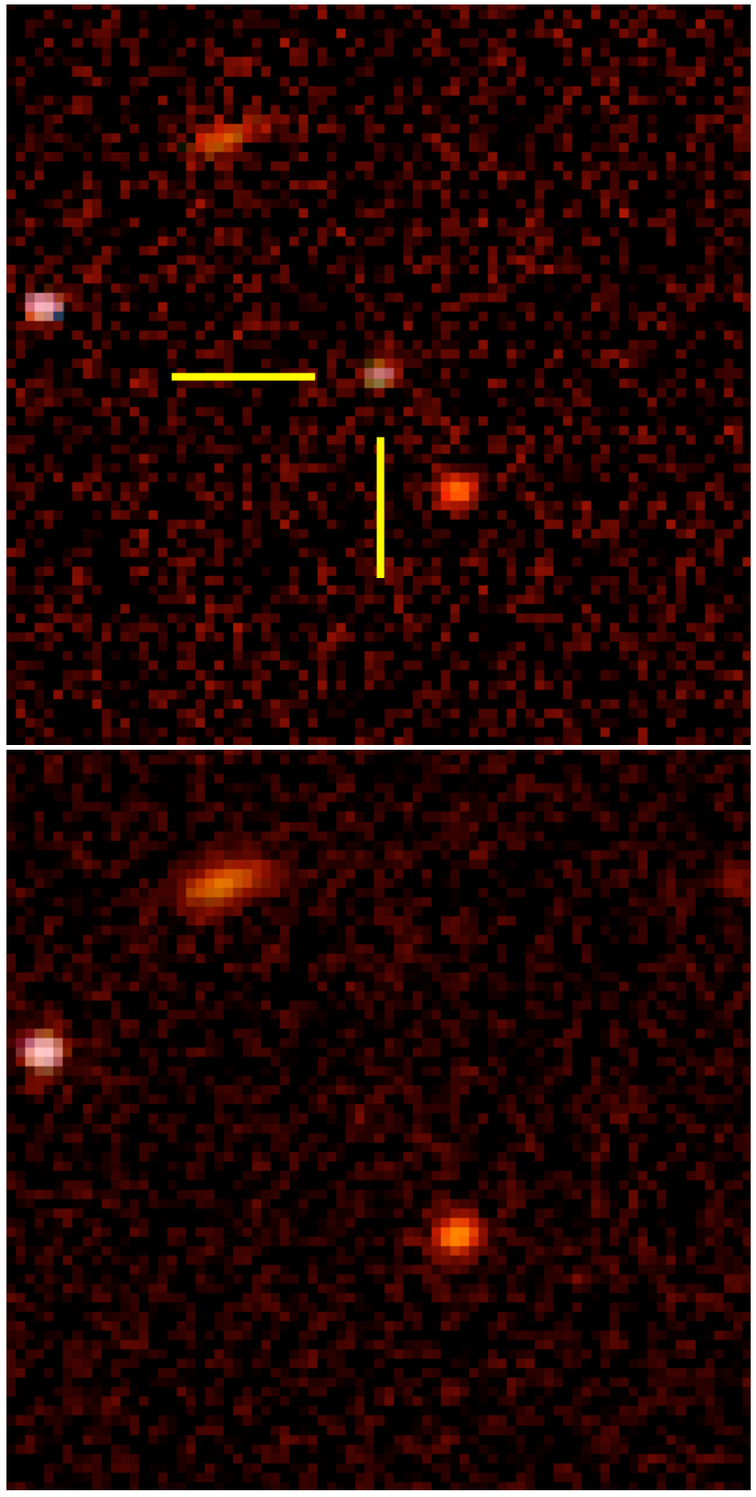


~500 additional SN Ia candidates
with good light curves

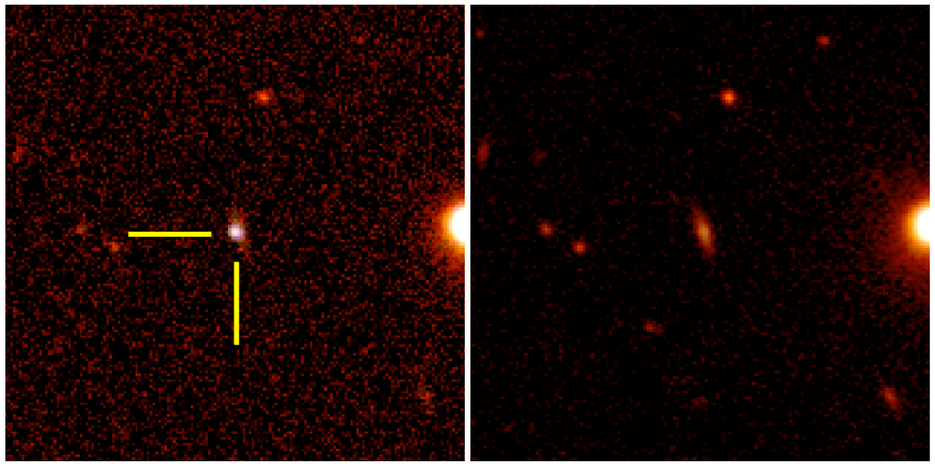
SN2005hk

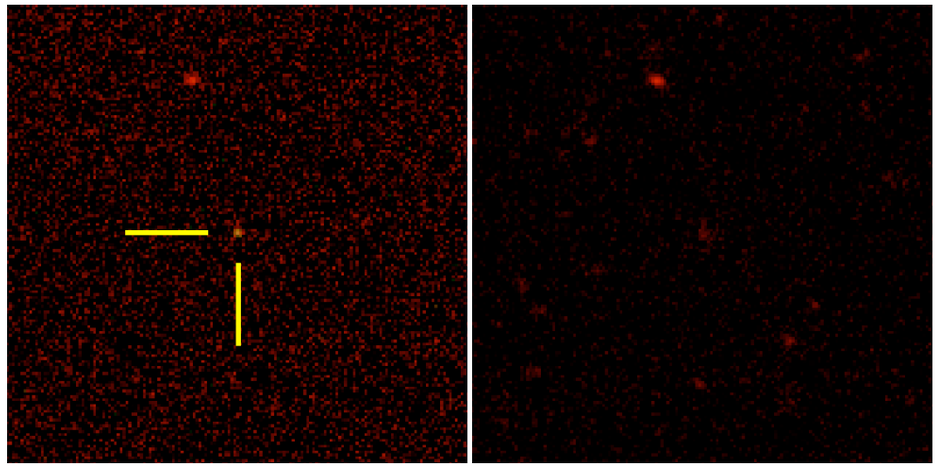
SN2005ja

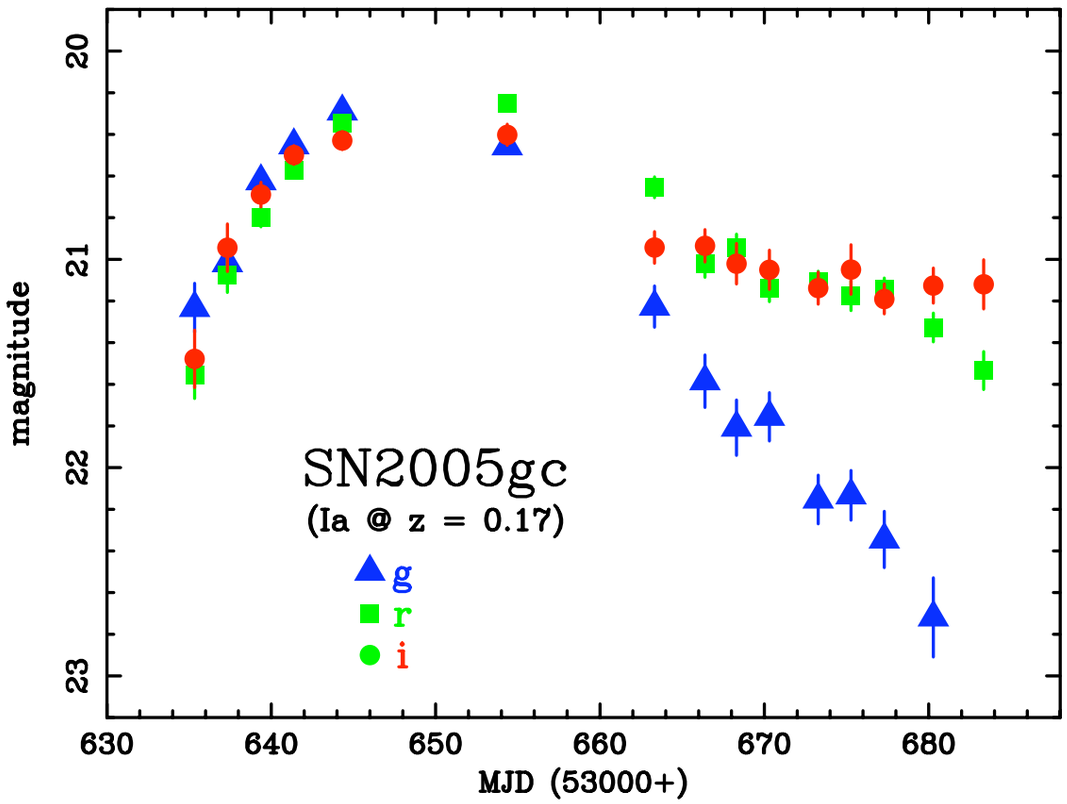
Ia-pec
z=0.0131

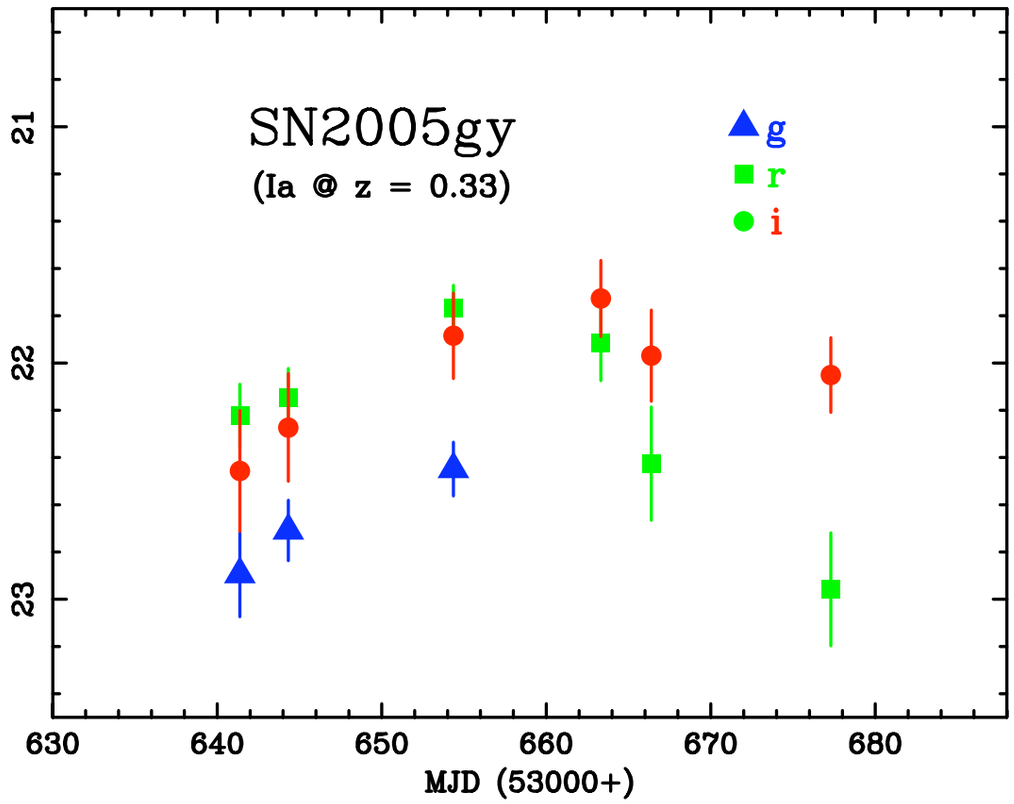


Ia
z=0.322



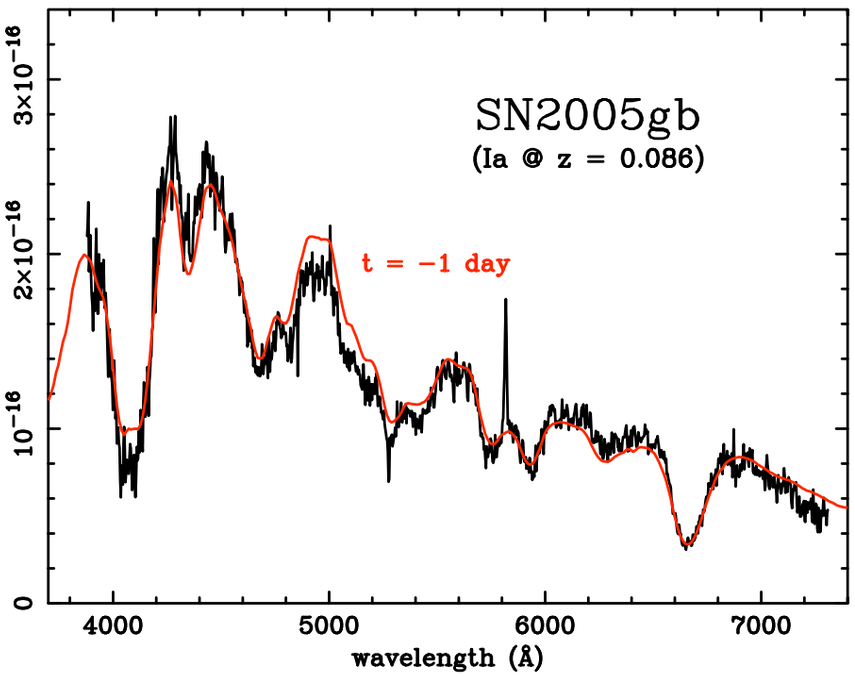


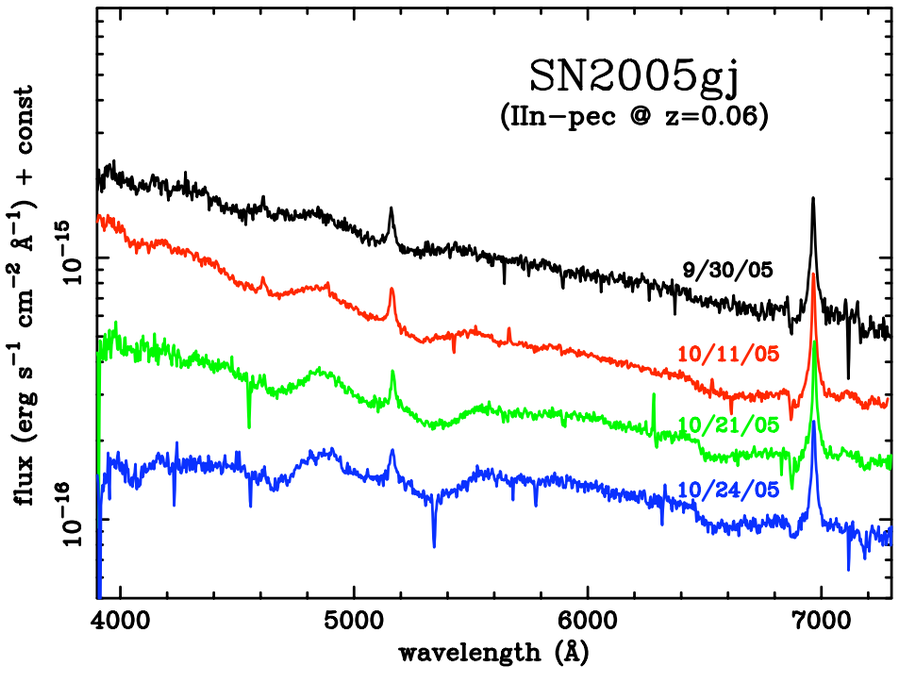




preliminary light curves

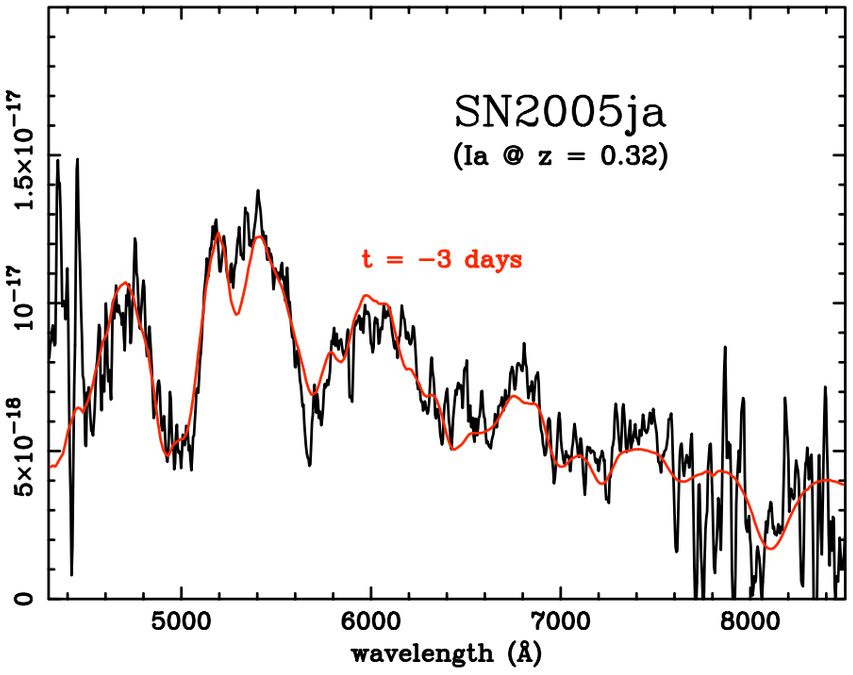
MDM

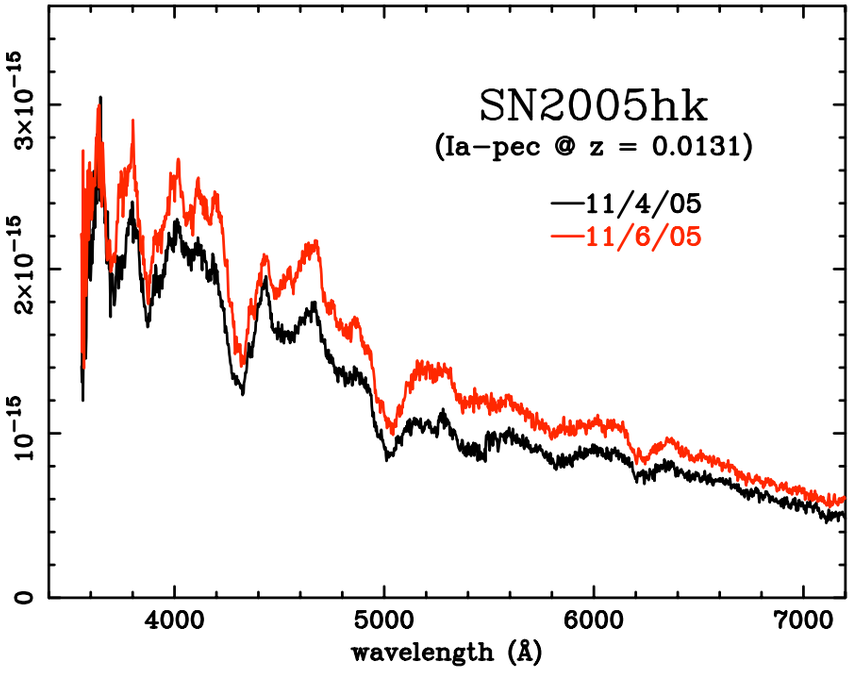




MDM

HET

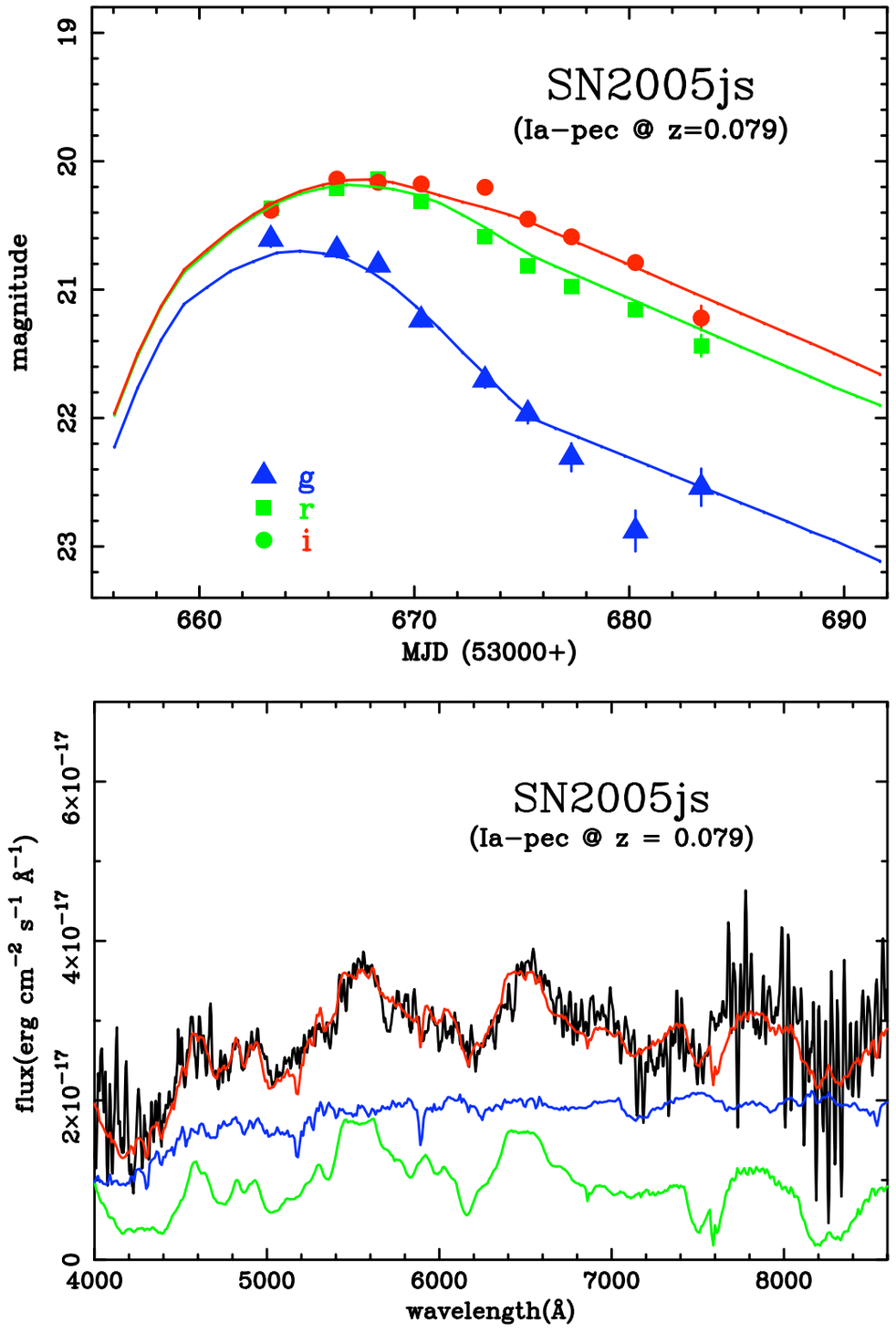




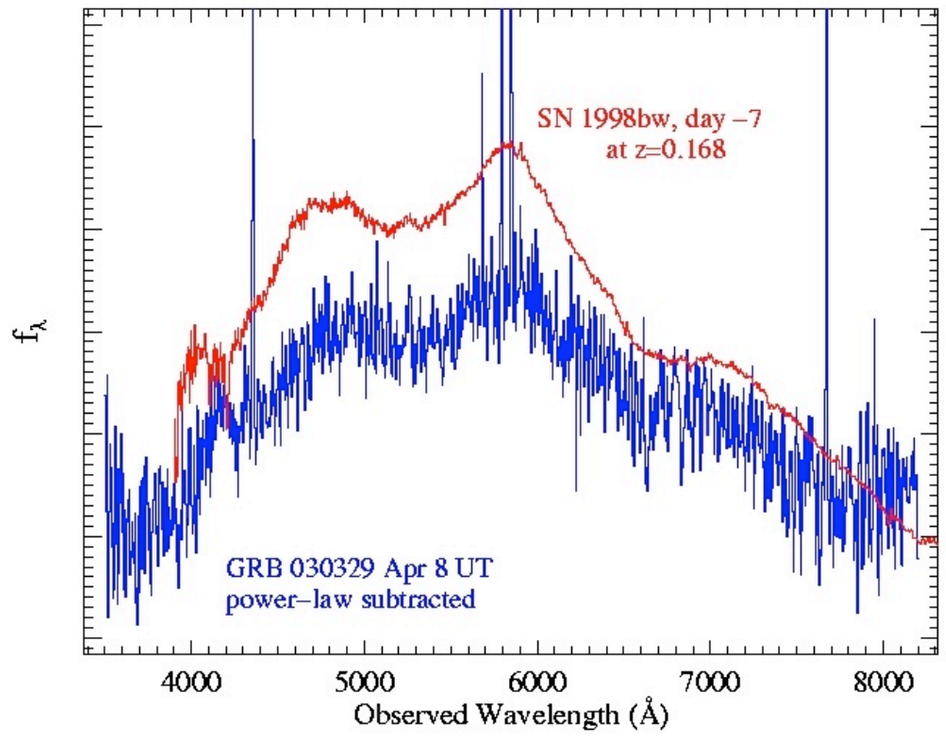
ARC

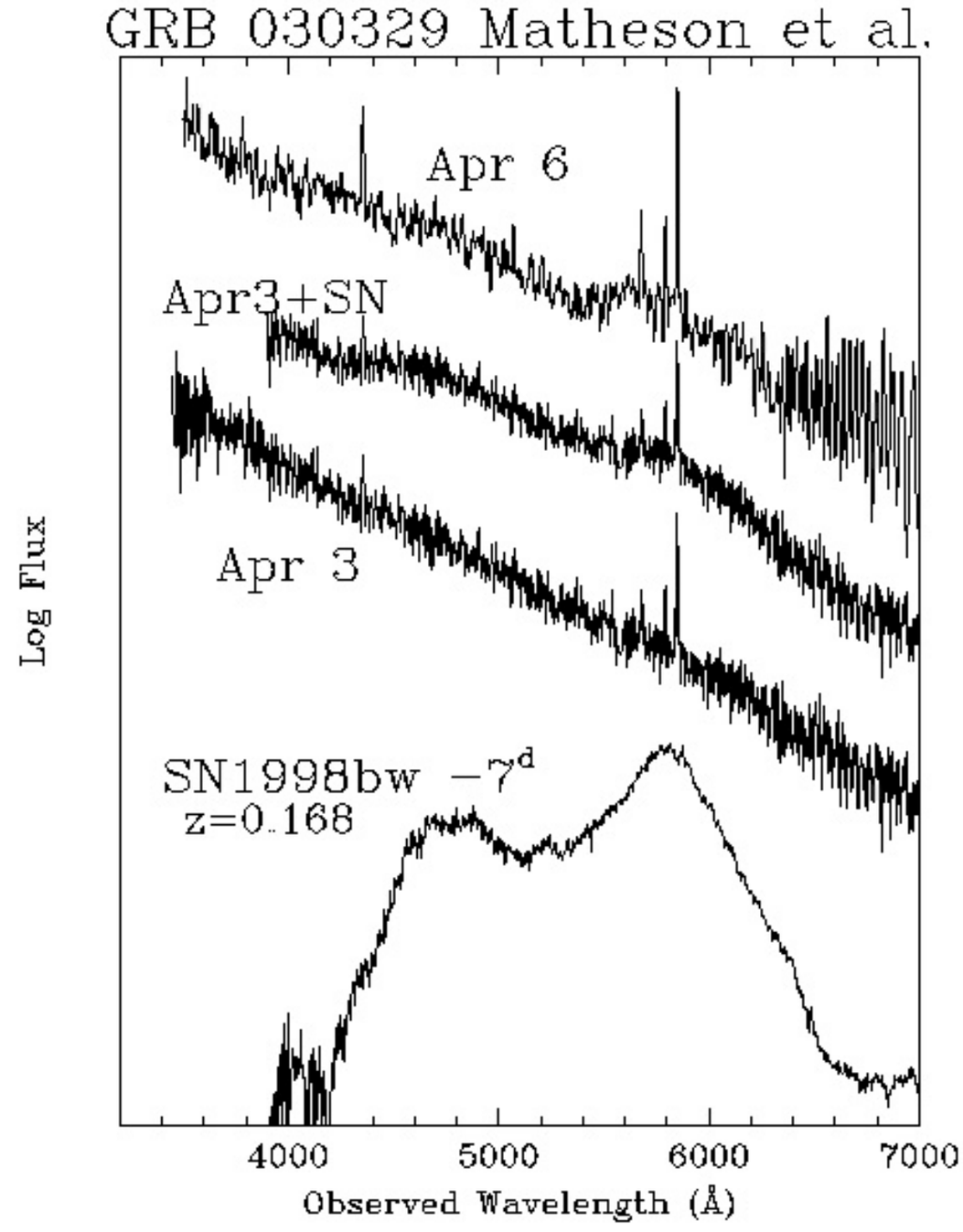
Peculiar SNe

- Large survey area -> catch and select peculiar objects
- Can be color-typed if photometrically distinct:
  - underluminous 1991bg-like Ia
  - overluminous 1991T-like Ia
  - Ib/c hypernovae
  - IIn?



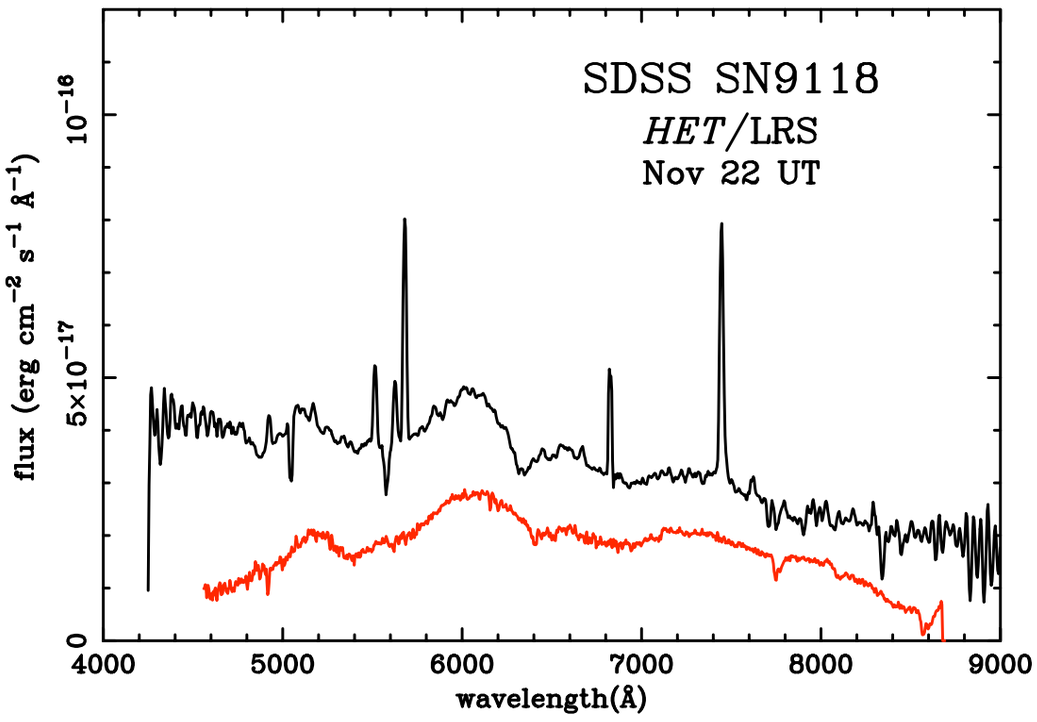
Hypernovae and GRB

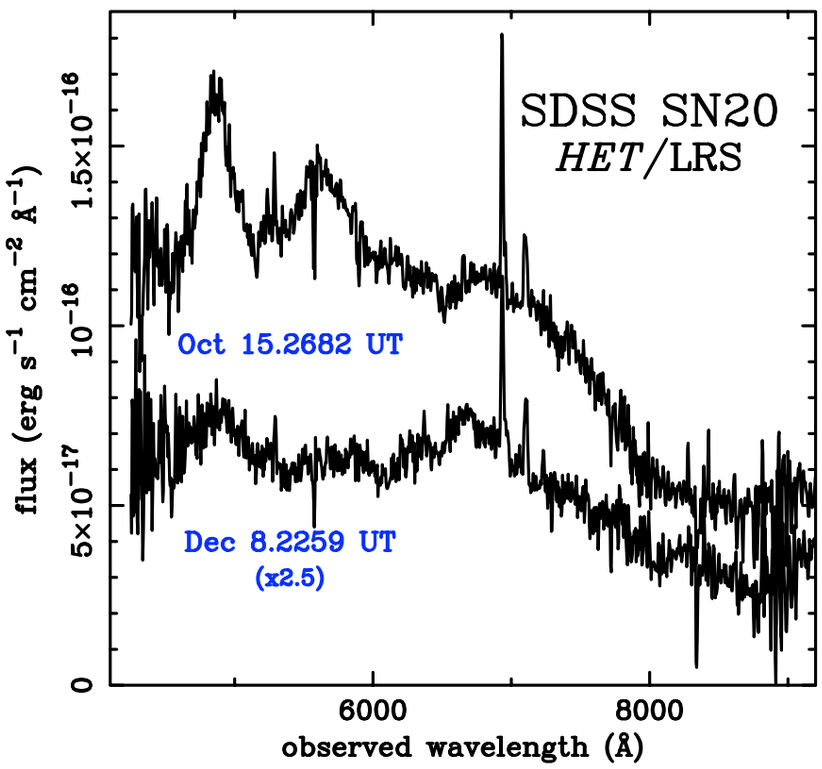


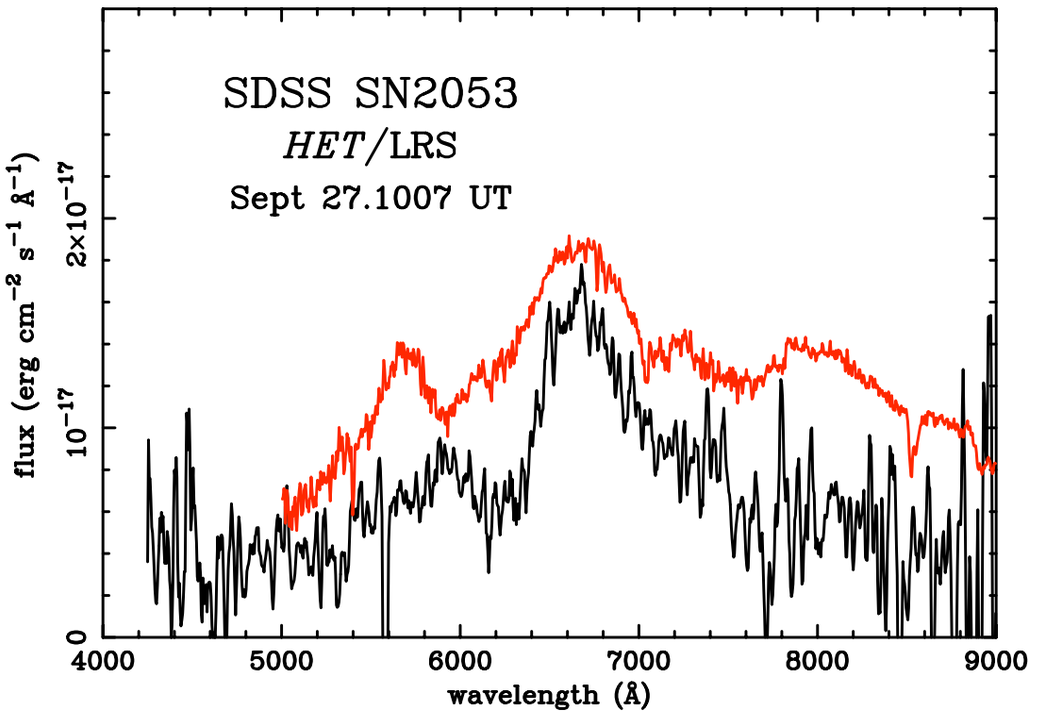


Matheson et al., 2003, GCN 2107, 2120

- Discover Ibc hypernovae in the optical
- Radio follow-up
- Search for gamma-ray flux from *Swift*
- X-ray follow-up if caught early







Plans for 2006

- Automate scanning process and minimize human interaction
  - allows us to put in more fakes - efficiency calibrator for population studies, etc.
- Find and follow up other types of SNe: II-P, IIn, Ibc, Ia-pec
- Densely-sampled multi-epoch spectroscopy of selected nearby targets
  - search for spectral sequence
  - help reduce dispersion of Ia as distance indicators
  - rare types